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DEVELOPMENT OF ELEMENTS OF A HIGH T_c SUPERCONDUCTING CABLE

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PROGRAM SUMMARY

The goal of the program is the development of materials and processes for the fabrication of a composite superconductor element made of a superconducting coating on a supporting fiber. The composite will also include a barrier layer between the fiber and the superconductor and a protective layer on the surface.

PROGRAM STATUS

The program is divided into three phases which correspond roughly with the three years of the program. The first phase is the development of textured polycrystalline $YBa_2Cu_3O_y$ (Y-123) with improved critical current carrying capacity. Phase II is the development of materials and methods for the composite conductor fabrication. Phase III is the scale-up of the process to demonstrate the capability to form continuous conductors. This report describes progress and accomplishments of the second quarter of the program. Tasks relevant to the first year of the program will be discussed in order. Specific accomplishments will be listed in the next section. To coordinate the timing of the reports on this program with the other DARPA sponsored superconductor programs, this report covers four months--November 1988 through March 1989. Subsequent reports will be at three month intervals.

Task I-1: Quantify the effects of the degree of crystallographic orientation on J_c The effects of temperature, applied magnetic fields, and field direction are being determined on Y-123 bulk samples made by aligning powders in a magnetic field and then sintering to densify the sample. We have developed a process for making well-aligned Y-123 bulk samples. Measurements of properties are now underway. The J_c values of these samples are of the order of $500A/cm^2$ at 77K and 0T applied field. This value is lower than would be expected from comparison with published values for unaligned samples and considering the expected reduction in J_c from published results on bicrystal films. Recent results indicate problems in the purity of the oxygen we used for sintering and post-sintering oxidation. This task was scheduled for completion in this reporting period. As described in the PROBLEM AREA section of this report, work on this task

will be continued into the next quarter in light of the importance of texturing on the critical current in polycrystalline samples.

Task I-2 Demonstrate improvements in critical current density using bulk, textured polycrystalline samples and thick or thin films This task is a key part of the effort. It is clear from work here and elsewhere throughout the world that very high critical currents can be obtained in thin films grown epitaxially on single crystal substrates. Polycrystalline samples, on the other hand, have much lower J_c values due to easy flux penetration and motion in the grain boundaries. Our efforts have been directed toward using several different techniques to make polycrystalline samples with controlled grain alignments in an attempt to minimize the weak links at the grain boundaries. We need to know the real limitations on J_c in polycrystalline samples with the grains aligned in the most favorable configuration for conduction, with the c-axes of all grains aligned in a common direction. Therefore is is proposed that the efforts on this task originally scheduled for completion after nine months be continued through the first year of the program.

Earlier work here showed noncrystalline sputtered films of Y-123 on $SrTiO_3$ single crystals which are subsequently annealed at about 900°C formed epitaxially aligned crystals up to thicknesses about 0.3 micrometers and lost the epitaxy at higher thicknesses. Initial experiments aimed at imposing a temperature gradient through the film thickness during annealing were inconclusive in demonstrating an improvement in the thickness of the epitaxial layer. The crystallization kinetics of the as-sputtered films are now under study.

Task I-3 Introduce flux pinning sites into Y-123 The aim here was to improve the J_c within the grains by introducing inhomogeneities in the sample to act as flux pinning centers. It is clear now that the overriding problem in polycrystalline Y-123 samples is not intragrain J_c but low intergrain J_c. Therefore it is suggested that this task be delayed with more attention directed toward Task I-2.

Task I-4 Develop a low impedance electrical connection This task is completed.

Task II-1 Develop Y-123 powder with improved lamellar structure This task is scheduled to begin in the next quarter of the contract.

Task II-2A Substrate selection Although not scheduled for effort until next quarter, some work has already been started on this task. Metal substrates are preferable to ceramics due to the much better thermal expansion match with Y-123. Metals, however, do present more difficulties in interdiffusion with the Y-123 and place more emphasis on the development of effective barrier layers and on low temperature fabrication processes.

Task II-B Barrier coating selection Effort was begun early on this task which is an essential part of a composite conductor development. Candidate materials have been identified which are in equilibrium with Y-123 (Y_2BaCuO_5 and $BaZrO_3$) or relatively benign in contact with Y-123 (ZrO_2, MgO, and $SrTiO_3$ are examples). It may be that a dual layer barrier will be required to isolate the substrate effectively from the metal substrate.

ACCOMPLISHMENTS

Task I-1

A process has been developed for making well aligned, bulk polycrystalline Y-123.

Improved alignments are shown to develop as a result of the grain growth accompanying longer sintering times.

Aligned materials have been found to be more difficult to densify by sintering than unaligned samples--a disadvantage.

Transport critical currents have been measured on aligned samples. J_c versus temperature, applied field, and applied field direction have been determined. The best values at 77K are 660 (0T) and 200 A/cm^2(0.5T). A slight minimum in J_c versus applied field is found for values about 7 mT which has been attributed to onset of flux penetration into the grains.

Task I-4

Low resistance contacts have been formed on Y-123 using painted Ag epoxy without the curing agent which is subsequently annealed at 500°C in flowing oxygen. The contact resistance is below 20 micro-ohm/cm^2 with current densities through the contact approaching 100 A/cm^2.

Task II-2A

Screening of potential substrate materials showed metals to most closely match the thermal contraction of Y-123 during cooling and concurrent oxidation.

Task II-2B

Initial screening of barrier layer materials show silver to be the best conducting material with Y_2BaCuO_5 and $BaZrO_3$ the least reactive insulating materials.

PROBLEM AREA & PROPOSED SOLUTION

Increased effort is needed on Tasks I-1 and I-2. The clarification of the properties of polycrystalline, aligned materials is a crucial ingredient of the understanding of the J_c limitations of Y-123. It is proposed that work be continued on characterization of the magnetically aligned samples. This requires reduction of the effort in some other area. The proposed work under Task I-3 would be delayed. This task is aimed at increasing the J_c inside the grains. It is clear now that the principal mechanism inhibiting the attainment of high J_c values in polycrystals is intergranular weak links. Therefore it is proposed that planned work on Task I-3 be delayed and the effort concentrated on intergranular J_c.

GOALS FOR NEXT QUARTER

Task I-1 Complete annealing studies in purified oxygen and determine annealing effects on J_c of magnetically aligned bulk samples.

Task I-2 Continue studies of epitaxial Y-123 formation from sputtered films. Initiate effort in situ sputtered films.

Task II-1 Initiate investigation of lamellar structure Y-123 powders.

FINANCIAL STATUS

All values are cost plus fixed fee total costs.

TOTAL FUNDING REQUIRED FOR EFFORT 01Sept88 through 31Aug91 (36 months)	$2,424,530
CURRENT AUTHORIZATION 01Sept88 through 31Jan90 (17 months)	900,000
FUNDING EXPENDED TO-DATE 01Sept88 through 31Mar89 (7 months)	297,427
FUNDING ESTIMATED TO END OF FISCAL YEAR 01Sept88 through 30Sept89 (13 months)	660,000